# TABLE OF CONTENTS (1/2)

- **REPORT OBJECTIVES AND METHODOLOGY** 6
- **SCOPE OF THE REPORT** 12
- **EXECUTIVE SUMMARY** 14

## 1- INTRODUCTION 32
- Global technology roadmaps
- Automotive market status
- Autonomous vehicle – the disruption case
- Robotic vehicle market trend
- Robotic vehicle regulation
- Robotic vehicle sensing technology

## 2- MARKET FORECAST 56
- 2006–2032 Global vehicle sales forecast
- 2017–2022 Robotic vehicle roll-out scenario
- 2017–2022 Sensor system volume forecast (in Munits)
- 2017–2022 Sensor semiconductor ASP forecast (in $)
- 2017–2022 Sensor system ASP forecast (in $)
- 2017–2022 Sensor semiconductor revenue forecast (in $M)
- 2017–2022 Sensor systems revenue forecast (in $M)
- 2017–2022 Total revenue forecast robotic vehicle (in $M)

## 3- COMPANY ECOSYSTEM 78
- Noteworthy news autonomous vehicle companies
- Noteworthy news sensors for autonomous vehicles
- Robotic vehicle sensor ecosystem
- Baidu Appolo ecosystem
- Robotic vehicle supply chain
- Robotic vehicle computing supply chain

## 4- LIDARS 85
- Lidar applications
- 2002-2030 ASP forecast
- 2016-2032 Automotive and robotic vehicle Lidar market ($B)
- Civilian Lidar players
- Comparative chart – current offering
- Comparative chart – future offering
- Solid state roadmap

## 5- RADARS 98
- Historical timeline
- Frequency regulation
- 2016-2022 Radar module forecast (Mu)
- 2016-2022 Radar module forecast ($M)
**TABLE OF CONTENTS (2/2)**

- 2016-2022 Radar chipset forecast (Mu)
- 2016-2022 Radar chipset forecast ($M)
- Radar supply chain landscape
- Teardown summaries

### 6- CAMERAS 113
- Cameras applications
- 2017 Automotive camera distribution
- 2013-2023 Automotive image sensor forecast (Mu)
- 2013-2023 Automotive image sensor forecast ($M)
- 2013-2023 Automotive camera module forecast ($M)
- Automotive camera market trends
- Robotic vehicle camera market trends
- Emerging technologies

### 7- INERTIAL MONITORING UNIT 139
- IMU technology trend
- 2017-2022 Industrial IMU forecast ($M)
- Average system cost structure
- 1990-2025 RLG pricing per axis ($)
- 1990-2025 FOG pricing per axis ($)
- 2017-2022 Robotic car IMU forecast ($M – Units)

- Major players

### 8- GLOBAL NAVIGATION SATELLITE SYSTEM 139
- Technology
- Major players
- Transponders

### 9- COMPUTING TECHNOLOGY 165
- Automotive ADAS supply chain
- Robotic vehicle computing ecosystem
- Robotic vehicle platforms

### CONCLUSION 186

- Visions of the future 191

Appendix – Yole Développement 201
COMPANIES CITED IN THE REPORT

ABOUT THE AUTHORS OF THIS REPORT

Biography & contact details

**Pierre Cambou**

Pierre Cambou joined the imaging industry in 1999. Following an engineering degree from Université de Technologie de Compiègne in parallel with a master of science from Virginia Tech in 1998, as well as graduating from Grenoble Ecole de Management’s MBA, Cambou took several positions at Thomson TCS, which became Atmel Grenoble in 2001 and e2v Semiconductors in 2006. In 2012 he founded Vence Innovation, now called Irlynx, in order to bring to market a disruptive man-to-machine interaction technology. He joined market research and strategy consulting company Yole Développement as imaging activity leader in 2014.

**Guillaume Girardin**

Dr. Guillaume Girardin works as a Market & Technology Analyst for MEMS devices and technologies at Yole Développement, the "More than Moore" market research and strategy consulting company. Guillaume holds a Ph.D. in Physics and Nanotechnology from Claude Bernard University Lyon 1 and a M.Sc. in Technology and Innovation Management from EM Lyon School of Business.

**Yohann Tschudi**

Yohann Tschudi has been a member of the MEMS team since June 2017 at Yole Développement, the "More than Moore" market research and strategy consulting company. He graduated from the University Claude Bernard (Lyon, France) with a Master’s degree in high energy physics and did his PhD in particle physics at CERN (Geneva, Switzerland). He then worked in several companies as a data scientist and scientific software manager. During this time, he participated in the development of multiple AI-centered software packages (machine learning, deep learning) from the architecture to final tests. He joined Yole to develop their software activity.
REPORT OBJECTIVES

1. **To provide a scenario for sensors within the dynamics of the robotic vehicle market**
   - Sensor semiconductor ASP forecast, revenue forecast, volume shipments forecast
   - Sensor systems ASP forecast, revenue forecast, volume shipments forecast
   - Application focus on the sensor suite: Lidar, Radar, Cameras, IMU, GNSS, and Computing

2. **To provide in-depth understanding of the ecosystem & players.**
   - Who are the players / how does the robotic vehicle ecosystem relates to automotive ecosystem
   - Who are the key suppliers to watch and which technology do they.

3. **To provide key technical insight & analysis about future technology trends and challenges.**
   - Key technology choices
   - Technology dynamics
   - Emerging technologies and roadmaps
METHODOLOGY

• Our methodology in building our market forecasts is quite different to other market research companies’ methodologies:
  o Our approach is to build a model where data from product shipments, module sales, sensor production and player market share are all linked with detailed assumptions.

• To do so, we collect data from multiple sources including:
  o Open-source secondary data from industry observers OICA, UN, IMF…
  o Primary data from direct interviews and visits with sensor players.
  o Direct contacts and surveys with equipment & material suppliers.
  o Direct analysis from teardown reports: especially with System Plus Consulting.
  o From specific market surveys we previously held, in different areas such as mobile cameras, medical, or automotive sensors, among others.

• As a result, today we are able to present unique key market metrics that result directly from this primary research work:
  o The main advantage of this approach is to be able to deliver a scenario grounded in feedbacks from the players themselves.
  o We plan to update the market information presented in this study within 2-3 years.
METHODOLOGIES & DEFINITIONS

Market forecast model is based on the following elementary structured blocks:
Report sample
AUTONOMOUS VEHICLES - THE DISRUPTION CASE

Two distinctive paths for autonomous vehicles

2020 should see the first implementation of autonomous driving (AD)

Technology x Market Penetration

Improvement of cars as we know

Industrialization phase

Electronics Invades cars

Electric car matures

Automated driving

Robotic cars

New use cases

Below expectation “cars” fulfilling needs in a new plane of consumption

Yole Développement © August 2015

Acceleration: The speed of technology change doubles every technology shift
**ROBOTIC VEHICLE MARKET TREND**

Emergence of the robotic vehicle market

Cumulated production of robotic vehicles could reach 10M units by 2032.

In this time frame, production will climb 3 orders of magnitude:

- 8k in 2018 (3 years)
- 44k in 2021 (5 years)
- 400k in 2026 (7 years)
- 3.1M in 2032

Life cycle of each vehicle will be relatively short, in the order of 5 years.

*In 2032 we expect 5M robotic vehicle on the road*
ROBOTIC CAR MARKET TREND

Emergence of the robotic vehicle market – what we know of the next 5 years

Known facts and a few hypothesis to build 5 years prediction

Impact on supply chain

Technology will change

50k vehicles more ?

4K / 8K / 12k from Volvo

5k vehicles more ?

500 vehicles from FCA

300 vehicles expected

Launch in 2018

$1.5B financing

200 vehicles

200? 

50k vehicles more ?

Log
Number of vehicles produced

100,000

10,000

1,000

100


Google Waymo

Uber Volvo

Lyft GM

Baidu BYD

Mercedes-Benz

| Sensors for Robotic Vehicles - Sample
Robotic vehicles will face adverse market forces in the range of \(~$6.7T\) (car + taxi)

**Current Car use cases**
- Inner city
- Suburb 20-50 km
- Country side > 50 km

**Current transportation paradigm will be challenged**
- Week end escape by car
- Train
- Supermarket
- Car Renting

**Current non-car users**
- Plane
- Week end escape by car

**New car use cases**
- Over-night personal transportation
- Longer commute
- Other use cases still to be discovered
- Send kids to school/activities
- Senior people social activities
- Longer commute
- Send goods to the city

**Some of the current paradigm will be extended to new users**
- Car Renting
- Supermarket
- In city driving

**Car renting**
- Good deliveries
- Work/sleep during commute
- Reduce parking
- Limit number of cars

**Supermarket**
- In city driving

**Inner city**
- Supermarket
- Send goods to the city

**Suburb to suburb transportation**
- Senior people social activities

**As for most disruptive technologies one should expect most of the growth drivers to be out of current use cases**
- Negative impact
- Neutral impact
- Positive impact

Robotic transportation will face adverse market forces in the range of \(~$6.7T\) (car + taxi). Some of the current transportation paradigm will be extended to new users. As for most disruptive technologies one should expect most of the growth drivers to be out of current use cases.
Forecasted revenue from robotic cars

\(~$2.4T\) in 2032

$2.4T sales of cars / year to 1B owners
$2,300 spendings per car/year
x2 for other car ownership related spendings

\(~$4.8T\) world personal car spendings in 2017

\(~$1.9T\) world taxi spendings in 2017

75 large cities with efficient public transport
This cover 10% of the world population (750M people)
Public transport represent 15% of GDP of those areas
$20k average GDP per inhabitant in those areas

\(~$2.3B\) in-city world in-city public transport spending in 2017

New mobility service companies will benefit from AD technology

Robotic car offering could allow reduction in public transport investments

Car manufacturers and insurance companies will be disrupted

Economic benefit of autonomous driving

\(~$3.5T\) of added value generated by robotic cars in 2032
2018 Conclusions

• 2018 will be the year of initial launch of robotic vehicle fleets

• Lidars, Radars, Cameras and IMUs will be the main piece of sensing technology supporting this trend. Expected vehicle production will reach 400k by 2026, they will reach 3M range by 2032.

• For the manufacturing of the initial fleets, spendings on sensing equipment will hold the highest share at 41%. By 2032 sensing equipment spendings will still represent 26% of total capital spendings for robotic vehicles hardware.

• Solid state approaches and the benefit of technology scaling will help lowering the prices of sensing equipment while at the same time performance of those equipments will rise.

• Our forecast takes the assumption of a $190,000 robotic vehicle in 2017. The total robotic vehicle cost will lower toward $95,000 by 2032.

• Sensing system hardware will reach $9B in 2025 and $77B in 2032. 40% of revenue will be generated by lidars, 27% by cameras and 27% by IMUs.
ROBOTIC VEHICLE SENSOR REVENUE FORECAST

Volume & Revenue forecast

- **Lidar**
  - 2017: $1.6B
  - 2022: $7.5B
  - 2027: $31.5B

- **Radar**
  - 2017: $44M
  - 2022: $0.3B
  - 2027: $1.7B
  - 2032: $21B

- **Camera**
  - 2017: $0.6B
  - 2022: $4.2B
  - 2027: $21B

- **IMU**
  - 2017: $0.9B
  - 2022: $4.7B
  - 2027: $21B

- **GNSS**
  - 2017: $0.1B
  - 2022: $0.5B
  - 2027: $2.1B

@2018 | www.yole.fr | Sensors for Robotic Vehicles - Sample
• In 1992 it was relatively difficult to forecast the emergence of the mobile phone industry and the business model and technology of the iPhone which appeared in 2007, fifteen years later.

• In 2002 it was also relatively difficult to forecast the situation of Facebook (founded in 2004) and the economics of social medias in 2017, fifteen years later.

• We believe fifteen years from now we may live in a world transformed by robotic vehicle technology.

• In 2018, sensing and computing technologies are ready, the supply chain is already in motion.